Indian J. Met. Hydrol. Geophys. (1975), **26**, 4, 511-516

551.577 : 551.501.4 (283.253) (541.1)

Extreme rainfall studies of the Brahmani, the Burhabalang, the Rushikulya and the Subarnarekha river catchments

T. G. CHANGRANEY, S. K. DUBE and S. D. S. ABBI

Meteorological Office, New Delhi

(Received 29 November 1973)

ABSTRACT. The rivers of Orissa region are prone to frequent floods during the southwest monsoon season, primarily because of the region lies in the normal track of monsoon depressions that originate in the Bay of Bengal and cross Orissa coast in course of their westerly to northwesterly direction of movement. With a view to estimating their maximum flood potential, it is necessary to find the maximum average rainstorm depth that has actually been realised in various catchments and to estimate the maximum rainfall that can probably occur in these catchments. For this purpose, the present study has been made and comparative appraisal made of the extreme storms rainfall depths thus arrived at. The present study is confined to the Brahmani, the Burhabalang, the Rushikulya and the Subarnarekha river catchments.

1. Introduction

The plains of Orissa State particularly the deltaic areas get floods, not only due to rainfall in this region but also due to heavy rains in the upper reaches of the river flowing through the State. With a view to examine the optimum flood potential of these rivers, it is necessary to estimate the highest rainfall that has so far been recorded and also evaluate the extreme rainfall that can probably occur in the catchment areas of these rivers. For the purpose of design storm evaluation, extreme rainfall studies have already been carried out for the *Mahanadi* and *Baitarani* (Dhar *et al.* 1966, 1968 and Rao *et al.* 1975). This study is, therefore, confined to the *Brahmani*, the *Burhabalang*, the *Rushikulya* and the *Subarnarekha* river catchments (Fig. 1). The descriptions of the rivers are as follows :

The river *Brahmani* is known as the South Koel in the upper reaches and rises near Nagri village in the Ranchi district of Bihar. It is joined by tributary *Karo* and passes through Bonai, Talcher and Dhenkanal districts before it enters Cuttack near Garh Balrampur after traversing a distance of about 700 km.

The *Burhabalang* rises from the Similipal hills in Mayurbhanj district and discharges in the Bay of Bengal.

The river *Rushikulya* rises near Digi village on the eastern slopes of the eastern Ghats in Phulbani district at an elevation about 1000 metres. It runs through Ganjam plains and enters the Bay of Bengal at Ganjam.

The *Subarnarekha* rises in Chhotanagpur plateau in Ranchi district of Bihar and after traversing 62 km in Orissa State, it falls in the Bay of Bengal near Balasore.

2. Raingauge network

There are 90 raingauge stations distributed in the four river catchments under study as under :

Catchment	No. of raingauge stations	Area of the catchment (sq. km)	Network density
Brahmani	41	37,288	909
Burhabalang	9	4,334	482
Rushikulya	7	7,808	1,115
Subarnarekha	33	20,397	618

Amongst these 90 raingauges, 6 are India Meteorological Department observatories where, in addition to rainfall, other meteorological observations are also recorded at least twice a day.

3. Seasonal and annual rainfall distribution

Normal annual rainfall and normal southwest monsoon seasonal (June-September) rainfall for each station in the region based on data from 1901-1950 (India met. Dep., 1962) has been collected and isohyetal maps prepared (Fig. 1). The map depicts more or less identical isohyetal configuration with annual normal isohyetal pattern with respect

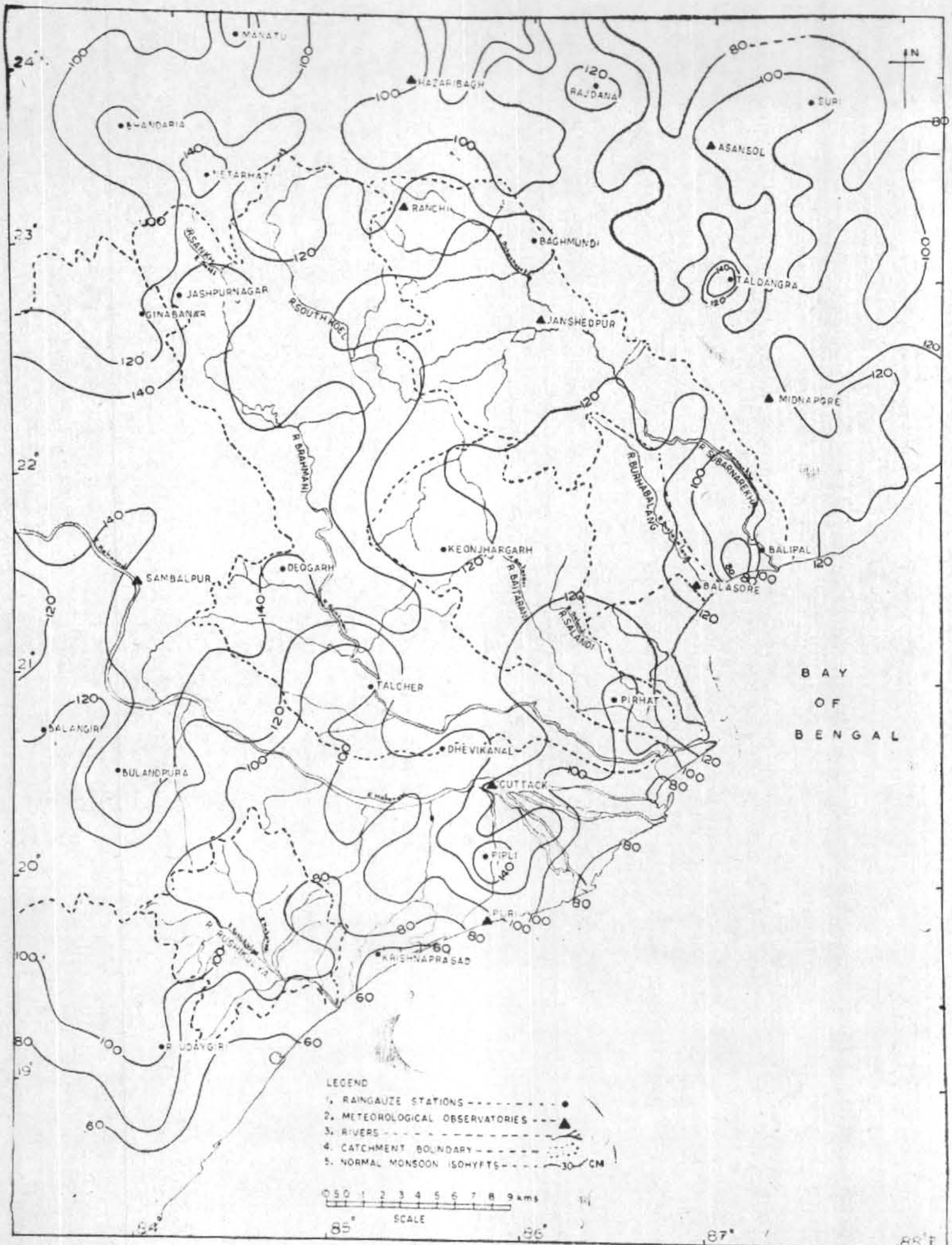

FIGURE 1

Fig. 1. Map showing rivers of Orissa and normal monsoon rainfall pattern

to the individual catchment as well as the whole region. Further, it is seen that southwest monsoon seasonal rainfall accounts for 75-80 per cent of the annual rainfall except in case of southernmost catchment of the region, *viz.*, *Rushikulya* where it is 65 per cent of the annual rainfall (Table 1). *Rushikulya* basin receives higher rainfall during the post monsoon period owing to the Bay storms following relatively southerly track. The normal annual rainfall of the Orissa State as a whole varies from 140 to 160 cm and the coefficient of variation of annual rainfall is only about 20 per cent which shows that the rainfall in the region is fairly dependable.

4. Synoptic situations associated with rainstorms

Heavy rainfall in the catchment areas of these rivers is generally caused due to the formation and movement of depressions/storms that originate in Bay of Bengal and move inland through Orissa coast in a westerly to northwesterly direction. There are occasions when low pressure areas that form over Bihar Plateau and adjoining regions also cause heavy rainfall in the catchment areas of Orissa rivers in course of their movement. Since, the major rain spells that occur in this region are associated with similar weather systems, the region has been assumed as a meteorologically homogeneous.

The duration and intensity of a rainstorm in a catchment is important from the point of view of the severity of the resultant flood. This in turn depends on the speed and the direction of movement of Bay depressions that traverse through the Orissa region. In general these disturbances cross the region under study little north of it and take about two days time. Hence the duration of intense rainstorm is generally two days or so in the region.

5. Evaluation of maximum average catchment rainfall

For scrutiny of the available rainfall data of this region the major rainstorms (Table 2) have been selected for detailed isohyetal analysis confined to individual catchments.

Brahmani catchment — Seven major storms (Table 2 a) were analysed by depth-duration method comprising of seven 1-day storms and four 2-day storms. The highest weighted 1-day maximum rainfall depth for the Brahmani catchment was 12·5 cm recorded on 30 July 1927 and the corresponding value for 2-day maximum storm was 20·8 cm recorded on 20-21 July 1920.

Burhabalang catchment — Eleven rainstorms of Burhabalang catchment were analysed and their depth-duration values calculated (Table 2 b). Amongst these, only six storms were of 2-day duration. It is seen from this table that the heaviest 1-day storm in this catchment occurred on 1 July 1940, when the weighted maximum rainfall depth of 20·8 cm was recorded in the catchment. Amongst the 2-day storms the highest storm was recorded on 4-5 August 1943, with its weighted catchment rainfall depth of 32·3 cm.

Rushikulya catchment — Six major rainstorms with four storms of 2-day duration listed at Table

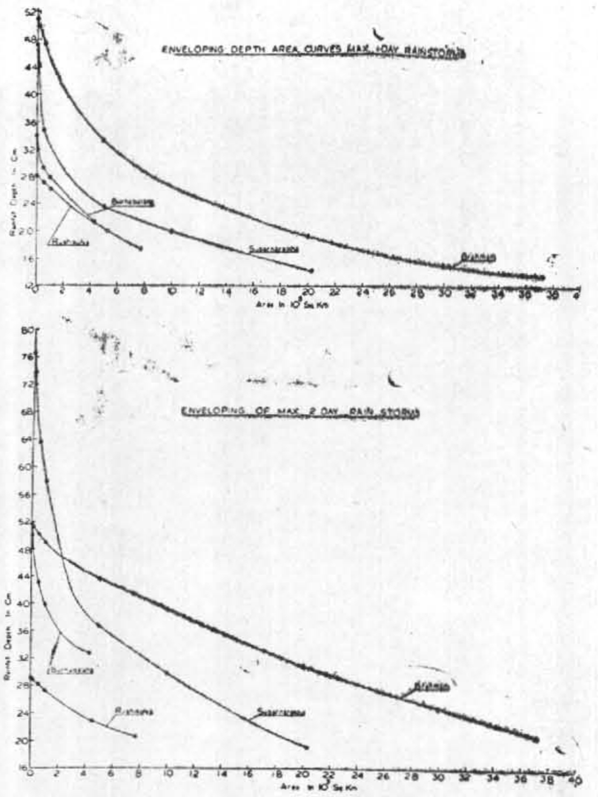

Fig. 2. Enveloping depth area curves of max. 1-day and 2-day rain storms

TABLE 1

Statistics of seasonal (southwest monsoon) and annual normal rainfall (cm)

Catchment	Rainfall		
	Annual	SW monsoon	Monsoon as % of annual
Brahmani	154	126	81·8
Burhabalang	162	119	73.4
Rushikulya	134	87	64·9
Subarnarekha	147	114	77·5

TABLE 2

Average isohyetal depths for different duration of major rainstorms occurred over different catchments

S. No.	Storm date(s)	Depth of rainfall (cm) 1-day	2-day
	(a) *Brahmani*		
1	8 Jul 1904	6·1	–
2	20-21 Jul 1920	11·2	20·8
3	28-29 Jun 1925	9·9	19·6
4	16-17 Aug 1926	8·9	14·2
5	29-30 Jul 1927	12·5	14·0
6	13-14 Jun 1936	6·6	–
7	1 Aug 1943	11·7	–
	(b) *Burhablang*		
1	8 Jul 1904	11·9	–
2	26 Jul 1906	7·9	–
3	25 Jul 1913	15·0	–
4	28-29 Jun 1925	9·1	14·2
5	29 Jul 1927	12·7	–
6	13-14 Jun 1936	6·4	12·7
7	30 Jun 1 Jul 1940	20·8	26·4
8	8-9 Oct 1941	13·2	20·3
9	1 Aug 1943	6·6	–
10	4-5 Aug 1943	19·6	32·3
11	19-20 Oct 1945	12·9	17·0
	(c) *Rushikulya*		
1	6-7 Oct 1900	17·3	19·3
2	14 Oct 1913	12·6	–
3	28-29 Jun 1925	11·4	17·5
4	17 Aug 1926	6·9	–
5	13-14 Jun 1936	8·9	15·7
6	20-21 Aug 1944	11·7	18·5
	(d) *Subarnarekha*		
1	8 Jul 1904	10·2	–
2	26-27 Jul 1906	13·2	18·5
3	20 Jul 1920	6·6	–
4	7 Aug 1920	9·7	–
5	29-30 Jul 1927	10·9	16·0
6	1 Jul 1940	8·6	–
7	4-5 Aug 1943	14·0	18·5
8	1 Sep 1957	6·9	–

2 (c) for Rushikulya catchment were analysed. The highest storm, unlike other catchments was recorded in the month of October with maximum 1-day average isohyetal depth of 17·3 cm on 7 October 1900, and maximum 2-day storm of 6-7 October 1900 with value 19·3 cm.

TABLE 3

Maximum 1-day and 2-day weighted storms rainfall depth picked up from the enveloping depth-duration curves

Catchment	Enveloping depth-duration values (cm) 1-day	2-day
Brahmani	13·4	20·8
Burhabalang	21·4	32·8
Rushikulya	17·3	20·7
Subarnarekha	14·1	19·2

Subarnarekha catchment — Seven major rainstorms (Table 2 d) comprising of 2-day storms, were analysed. It was found that highest 1-day maximum average catchment rainfall was 14·0 cm recorded on 5 August 1943. The highest 2-day maximum average catchment rainfall was 18·5 cm realised on 26-27 July 1906 and 4-5 August 1943. Both these storms have more or less identical time distribution.

From the above analysis, it is significant to note that highest 1-day maximum rainfall in the individual catchment has always been recorded in 2-day rainstorms and 1-day storms have yielded lower rainfall depths.

6. Enveloping within basin depth-area-curves

With a view to examine areal distribution of the extreme storm rainfall within the respective catchments, within-basin depth-area-curves were drawn for the individual catchments on the basis of isohyetal analysis of the storms listed (Table 2) and also enveloped (Fig. 2). The enveloping maximum weighted catchment rainfall depths thus arrived at are shown in Table 3.

The advantage of within-basin enveloping depth-area curves lies in their utility along with the enveloping depth-area curves of the meteorologically homogeneous region of which the basins understudy are constituent areas, in determining the specific area of storms transposition with respect to the each catchment and also evaluating corresponding, optimum rainfall intensity by sliding technique (WMO 1973).

7. Depth-area-duration analysis of rainstorms over Orissa region

Analysis of rainstorms is carried out for estimation of maximum rainfall provided the region is considered to be meteorologically homogeneous. This aspect has already been discussed in Sec. 4.

The region between Lat. 19°N, Long. 83°E. and Lat. 24°N, Long. 87°E (area about 220,000 sq. km) has been considered as a meteorologically homogeneous area for depth-area-duration analysis.

All the major storms that have occurred in these individual catchments as well as those storms that have affected Baitarni and Mahanadi catchments have been examined and the extensive ones listed (Table 4), were selected for detailed study. Separate isohyetal maps of 1-day and 2-day durations for these rainstorms were prepared and depth-area-duration curves drawn. From the 1-day and 2-day enveloping curves as shown in Fig. 3, the rainfall depths corresponding to the standard areas were picked up and are given as under:

Area sq. km	Rainfall depth (cm)	
	1-day storm	2-day storm
1,000	52·1	73·7
5,000	43·4	65·3
10,000	36·6	57·4
20,000	29·2	46·5
30,000	23·9	41·9
40,000	21·6	38·9
50,000	19·8	36·6
100,000	14·2	27·9
150,000	11·1	21·3

The rainfall depths corresponding to the four catchment areas is given in Table 5.

8. Estimation of probable maximum rainfall

In the estimation of probable maximum rainfall, it is first assumed that the causative factor for the extreme rainfall that have so far been recorded is the maximum rate of convergence in the atmosphere which is pre-requisite in precipitation producing mechanism. Therefore, the procedure for obtaining probable maximum rainfall involve transposition of the highest rainstorms and their adjustments for the moisture charge (WMO 1973).

Moisture maximisation — The moisture maximisation of rainstorms have been carried out by following the procedure based on studies by several workers (Paulhus and Gilman 1953, Dhar *et al.* 1968, Shenoy *et al.* 1970).

All the observatory stations in and around the Orissa region for which dew point temperatures are available from 1931 to 1960 have been considered.

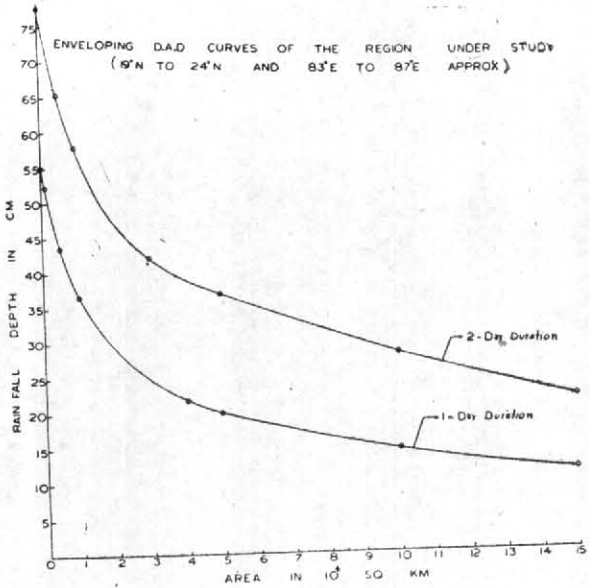

Fig. 3. Enveloping DAD curves

TABLE 4

Rainstorms analysed for the Orissa region as a whole (221,000 sq. km)

Storm date(s)	Weighted depth of rainfall (cm) for the region	
	1-day	2-day
26-27 Jul 1960	7·9	10·2
20-21 Jul 1920	6·8	12·7
28-29 Jun 1925	10·7	21·3
16-17 Aug 1926	7·3	14·2
29-30 Jul 1927	6·9	12·3
13-14 Jun 1936	7·9	15·5
30 Jun-1 Jul 1940	6·3	8·9
1 Aug 1943	9·4	—
4-5 Aug 1943	8·5	11·7

The persisting 24-hr maximum dew point temperatures on record were reduced to 1000 mb and the corresponding precipitable water values for each station were worked out. The storms that have been maximised for moisture charge are listed in Tables 2 and 4. For these storms dew point temperatures recorded during the period of rainstorms and on a day prior and subsequent to the storms duration were also considered. The precipitable water for each of the storms to be maximised was computed and by considering

TABLE 5

Comparative statement of extreme average catchment rainfall depths

Catchment	Enveloping weighted rainfall depth (cm)				Enveloping depth-duration values (cm) maximised for the moisture charge and depth-area duration values (cm)				Return period values (cm)			
	1-day		2-day		1-day		2-day		100 years		1000 years	
	DD	DAD	DD	DAD	DD	DAD	DD	DAD	1-day	2-day	1-day	2-day
Brahmani	13·4	22·3	20·8	39·7	19·7	31·8	29·5	58·4	11·4	19·5	14·8	25·5
Burhabalang	21·4	45·3	32·8	66·7	30·0	64·7	45·6	98·1	17·9	27·5	23·5	36·2
Rushikulya	16·2	39·3	20·7	60·5	26·6	56·1	33·9	88·9	17·9	26·7	24·0	36·8
Subarnarekha	14·1	29·0	19·2	46·5	20·2	41·5	27·5	68·3	11·7	18·1	15·2	23·4

the precipitable water for the corresponding persisting maximum dew point temperature, the maximisation factors were worked out. The enveloping moisture maximisation factors thus obtained for each of the river basins and the region as a whole, are given below:

Catchment of	1-day	2-day
Brahmani	1·47	1·42
Burhabalang	1·40	1·39
Rushikulya	1·64	1·64
Subarnarekha	1·43	1·43
Whole region	1·43	1·47

The depth-duration and depth-area-duration values have been multiplied by these values and moisture maximised values obtained as shown in Table 5.

9. Rainstorm transposition

It is seen from Table 5 that the maximum rainfall depths obtained for each catchment from enveloping depth-area-duration curves exceed appreciably from the moisture maximised depth-duration value indicating thereby excessive spatial maximisation involved therein. The isohyetal patterns of the rainstorms contributing to the envelopment of depth-area-duration curves were, therefore, examined and were found to be not even broadly conforming to the boundaries of the catchments. Further, these storms also depict two heavy rainfall cells, one in the deltaic/coastal portions of the catchments and the other in non-coastal areas. The normal monsoon seasonal isohyetal map also show similar rainfall distribution.

With a view to compare depth-area-duration values corresponding to the non-coastal areas of the catchments under study with the corresponding values derived by storm transposition technique, the highest storms on record were examined for super-imposition to the Brahmani catchment upto Barkot and between Barkot and Talcher and the Subarnarekha upto Ghatsila. The depth-area-duration curves shown in Fig. 3 are evolved by envelopment of the depth-area-duration curves of two highest storms of the region, *viz.*, 28-29 June 1925 and 29-30 July 1927. The latter storm was the highest on record for area upto 30,000 sq. km. The catchment area mentioned above are all less than 30,000 sq. km. Hence, the storm of 29-30 July 1927 was considered transposable for these catchments. This aspect was further examined by the application of 'sliding technique'. This storm was transposed over the catchment as per guidelines enumerated by Dhar (1972).

TABLE 6

Probable maximum rainfall depths estimated by storm transposition techniques

Catchment	Area (sq. km)	Weighted rainfall depth obtained			
		By S. T. (cm)	From enveloping DAD curves (cm)	By S. T. and a. m. c. (cm)	From enveloping DAD curves and a. m. c. (cm)
Brahmani upto Barkot	22,890	38·2	44·8	56·3	63·6
Brahmani between Barkot and Talcher	7,620	58.3	61.5	86·3	87·3
Subarnarekha upto Ghatsila	14,280	47·4	53·0	72·5	75·8

S. T. = storm transposition, a. m. c. = Adjusted for moisture charge at the catchment location

The weighted rainfall depths for the Brahmani catchment upto Barkot and the intermediate catchment upto Talcher and for the Subarnarekha upto Ghatsila were determined from the transposed 2-day storm of July 1927 and the same are given in Table 6. These values have been adjusted for moisture at the catchment locations and probable maximum rainfall values obtained and shown in Table 6.

10. Summary and conclusion

1. For evaluation of probable maximum rainfall in respect of the total catchment areas of rivers in Orissa, each catchment should be studied separately and enveloping depth-duration values maximised for the moisture charge.

2. For hydrological design purposes, extreme rainfall depths for the non-coastal areas of these catchments comprising of the upper and middle reaches of the rivers, may be obtained by application of storm transposition technique.

3. On the basis of 'sliding technique' and study of isohyetal configuration of rainstorms contributing to enveloping depth-area-duration curves, storm of 29-30 July 1927 was highest on record and considered transposable for the areas upto 30,000 sq. km. For larger areas, the rainstorm of 28-29 June 1925 yielded maximum rainfall depth.

Acknowledgements

The authors are grateful to Dr. P. Koteswaram, Director General of Observatories for his continued interest in hydrometeorological studies and Shri P. S. Harihara Ayyar, Director (Hydrometeorology) for his encouragement. Thanks are also due to Shri S. D. Gaur in preparation of this manuscript.

REFERENCES

Chow, V. T. 1964 *Handbook of Applied Hydrology*, McGraw Hill Book Co., New York, pp. 8-31.

Dhar, O. N. 1972 Manual of Hydrometeorology, Pt-I, India met. Dep., pp. 72-74.

Dhar, O. N., Mantan, D. C. and Jain, B. C. 1966 *Indian J. Met. Geophys.*, **17**, Spl. No., pp. 43-46.

Dhar, O. N. and Kamte, P. P. 1968 *Ibid.*, **19**, **3**, pp. 311-314.

Dhar O. N., Mhaiskar, P. R. and Ghose, G. C. 1968 *Ibid.*, **19**, **4**, pp. 413-420.

Dhar, O. N. and Mhaiskar, P. R. 1968 *Ibid.*, **19**, **4**, pp. 427-430.

Dhar, O. N., Aralikatti, S. S. and Tikko, M. R. 1968 *Irrigation and Power*, Journal of C.B.I.P., **28**, **2**.

Paulhus, J. L. H. and Gilman, C. S. 1953 *Trans. Amer. geophys. Un.*, **34**, pp. 701-708.

Rao, D. V. L. N., Abbi, S. D. S., Changraney, T. G. and Bahl, H. D. 1975 Hydrometeorology of Mahanadi catchment, Met. Monogr. Hydrol./No. 3/1972, India met Dep.

Shenoy, R. C., Changraney, T. G. and Raman, P. K. 1970 *Indian J. Met. Geophys.*, **21**, pp. 253-258.

World Meteorological Organisation 1973 Manual for Estimation of Probable Maximum Precipitation for Operational Hydrology, Report No. 1, p. 37.